Rhodora

JOURNAL OF THE

NEW ENGLAND BOTANICAL CLUB

Vol. 63 July, 1961 No. 751

SPORE STUDIES IN THE GENUS CYSTOPTERIS. I. THE DISTRIBUTION OF CYSTOPTERIS WITH NON-SPINY SPORES IN NORTH AMERICA

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In an article entitled "An Overlooked North American Fern" the late A. H. G. Alston (1951), of the British Museum, called attention to a number of western collections of *Cystopteris* with rugose-verrucose spores (Fig. 1, C, B and D) rather than the spiny spores (Fig. 1, A) found in normal *Cystopteris fragilis*. Such plants had been known from Eurasia for many years and were frequently treated as a distinct species, *C. dickieana* Sim or *C. Baenitzii* Dörfl., by European botanists. In the past ten years Irene Manton (1950) has dealt with the history and cytology of such plants from Europe and Greenland; Ira L. Wiggins (1954) has compared the morphology of such plants from Alaska with that of *Woodsia glabella*; while D. Löve and N. J. Freedman (1956) have published a review of the literature in regard to the nomenclature and distribution of these plants and reported a number of new localities.

My own interest in the spores of this genus was the result of the finding of rugose-verrucose spores in two puzzling collections from Northern Michigan. After the publication of the Alston article I made a survey of all collections of *Cystopteris* from Michigan then in the herbaria of the University of Michigan and the Cranbrook Institute of Science. Three more collections with such spores were found and reported (Hagenah, 1955). In the meantime non-spiny spores had been reported in material from Ontario and Minnesota by C. V. Morton (1952). In discussing *Cystopteris fragilis* as a subject for intensive research he wrote as follows (l.c.), "The whole problem has been complicated recently by Mr. Alston's report of another species, *Cystopteris Dickieana*, from the United States. What is this plant, indistinguishable from *fragilis* morphologically (or is it?), but with spores similar to those of a *Woodsia*? Can a really valid

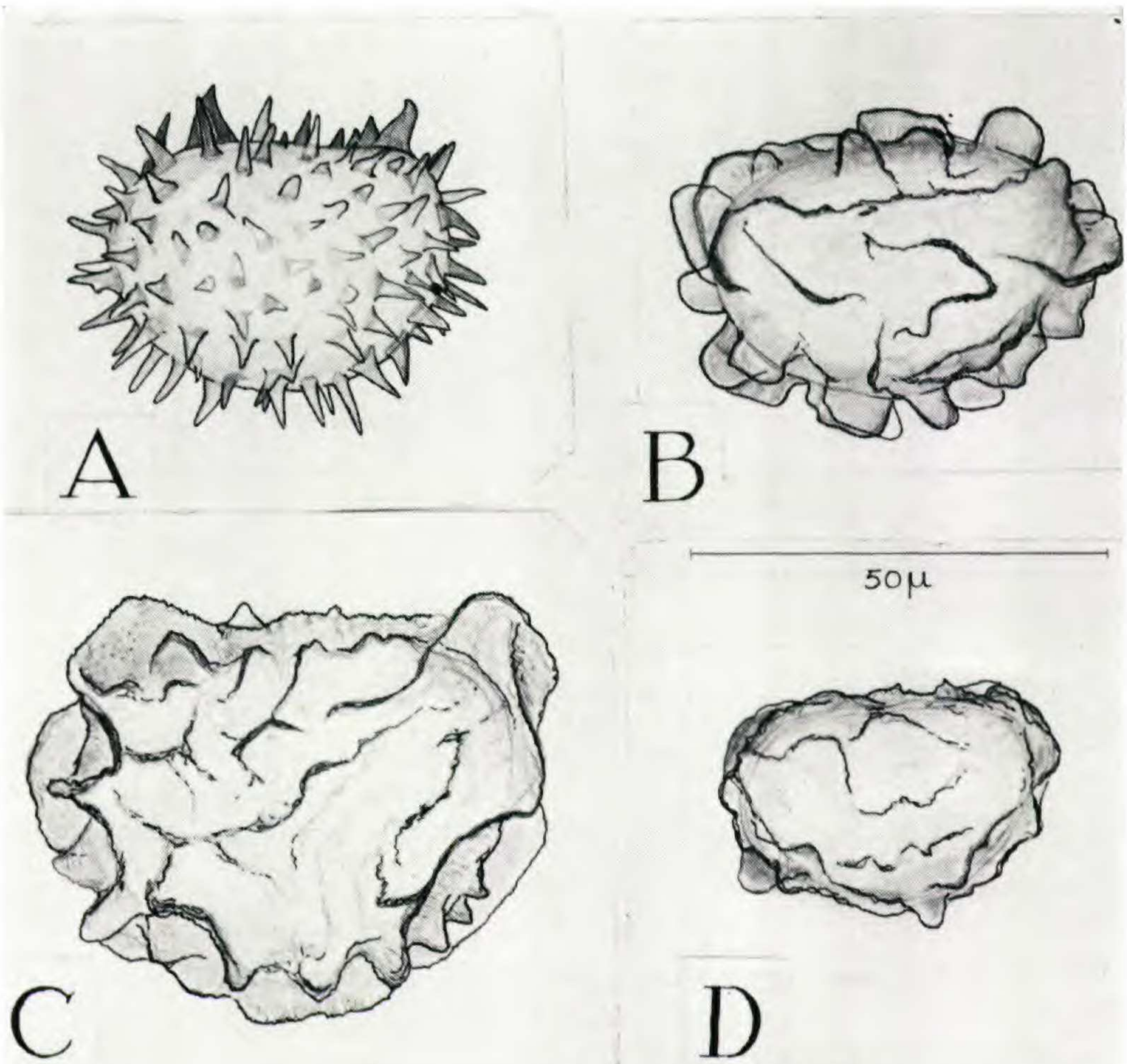

FIGURE 1. A. Typical spiny spore, Lake Michigamme, Marquette County, Michigan, *Hagenah 2580* (BLH). B. C. and D. Non-spiny spores:
B. Steamboat Springs, Routt County, Colorado, *Goodding 1625* (GH);
C. Diana Bay, Hudson Strait, Quebec, *Gardner 39570* (GH);
D. Wiseman, Alaska, *Scamman 2179* (GH). Camera lucida drawings by W. H. Wagner, Jr.

species have the improbable range Scotland, Scandinavia, Siberia, Spain, Algeria, Turkey, Persia, Alaska, Alberta, California and Mexico? It seems as though "*Dickieana*" occurs sporadically throughout the range of *fragilis*. The study of this question will involve field work, as well as the examination of the spores of hundreds of specimens." That same year, and again in 1953, I revisited the location at Mt. Bohemia, Keweenaw County, Michigan, where I had made my first collection of such plants. Both years the plants in that colony had non-spiny spores, showing that this was the regular condition for that colony. A plant transferred from this station to the University of Michigan Botanic Gardens was studied cytologically by W. H. Wagner, Jr. (1955), and found to have the same chromosome number (n=84) as that reported by Manton for plants from Scotland, Norway and Greenland.

Stimulated by Morton's comments (l. c.) and by the findings just described in Michigan collections, I decided to map the distribution of the non-spiny (rugose-verrucose) type of spore in North America. This work was undertaken as part of a comparative study of some American members of the genus. Some results of these studies have been reported elsewhere (Wagner and Hagenah, 1956a and 1956b). A comprehensive survey was made possible through the loan of the North American collections of *Cystopteris* by the Gray Herbarium. I wish to thank the staff of the Gray Herbarium for the opportunity of examining this fine series of specimens. This collection, containing over 900 sheets of specimens and including material from nearly every state and all of the Canadian provinces, provided an exceptional cross-section of the genus as it occurs in North America. In addition to the wide coverage it provided, a survey of this material was desirable because the collections from the northeastern United States and Canada had been studied and named by C. A. Weatherby (1935) during his investigation of the *C. fragilis* complex in that region. I am grateful to the Department of Botany of the University of Michigan for providing laboratory facilities during the preparation of the slides and especially to Dr. Warren H. Wagner, Jr., of that department, for his many suggestions and invaluable assistance, including preparation of the spore drawings.

In the spore survey, preparations were made from all collections on which there seemed to be a chance that the spores were sufficiently mature for study. In some cases this resulted in slides with no mature spores although a likely pinnule had been selected by examination under magnification. In many cases where there were two or more well-developed plants on the same sheet, preparations were made from each, especially when there seemed to be some variation in their appearance. To make the preparations a drop of Euparal was placed on a slide, a drop or two of alcohol placed on the spore-bearing pinnule selected, the sporangia and spores picked up with a needle and placed in the Euparal. Between each preparation the needle was flamed over an alcohol burner to prevent mixing. After stirring to distribute the spores in the medium, a cover-slip was added and pressure applied. While this method resulted in a fairly thick slide due to the presence of numerous sporangia, it was felt that the presence of sporangia, especially some with the spores still inside, was desirable. In a few cases some contamination on the herbarium sheet was found through the presence of more than one type of spore. New preparations were made in such cases.

The spores of *Cystopteris* may be described briefly as bilateral, monolete, convex on one side, and either flat or concave on the other. The latter condition results in a "bean-shaped" profile. The outer layer, called the "sculptine" by Harris (1955) in his study of the spores of New Zealand ferns, has been found by Robert F. Blasdell (1959) to have three basic patterns of which only two, the echinate or spiny type (Fig. 1, A), and the rugose-verrucose type (Fig. 1, B, C and D), occur in North America. There is considerable variation in sculpturing within these basic types. In this study I have not as yet separated the rugose-verrucose spores into sculpturing sub-types and will refer to any of the variants of this type as "non-spiny."

When prepared in the manner just described it was found that the outer layer was generally more darkly pigmented in the non-spiny spores than in the spiny members of the *fragilis* complex. The outer layer seemed to be more brittle in the non-spiny spores and in a few cases cracked and flaked off under pressure. Both spiny and non-spiny spores showed a considerable tendency for the spores to fail to fill out to normal size or shape. However, the two basic types could still be distinguished for the outer layer tended to assume normal sculpturing in such aborted spores. Even in small, completely aborted spores from plants with spiny spores some definite spines were evident. The sculptine pattern could be determined under 100x magnification. For more detailed examination and for measurements, 430x was used.

The genus *Cystopteris* in North America consists of *C. bulbifera*, *C. montana*, and the *C. fragilis* complex, the last being the most widely distributed and the most variable. In the collections which were sufficiently mature for the spore sculptine type to be determined, only spiny spores were

Spiny and non-spiny spore types in *Cystopteris fragilis* as represented in the Gray Herbarium collections.

	Area	Total Colls.	Percent Non-spiny	Percent Spiny
I	No. Quebec, Labrador, E. Arctic incl. Greenland	48	52.1%	47.9%
II	So. Quebec, New Brunswick, Nova Scotia & Newfoundland	91	3.3	96.7
III	Eastern United States except Mich., Wisc., & Minn.	125	0.8	99.2
IV	Great Lakes Region: Ontario, Mich., Wisc., & Minn.	48	16.7	83.3
V	U. S. from Mississippi R. to the Rockies	37	5.4	94.6
VI	Rocky Mt. & Pacific Coast States & Western Canada	162	60.5	39.5
VII	Alaska	27	18.5	81.5
	Total	538	26.4%	73.6%

found in *C. bulbifera* (117 collections) and *C. montana* (17 collections). However, in the *C. fragilis* complex non-spiny (rugose-verrucose) spores were found in slightly more than 26 per cent of the 538 collections in which the sculptine pattern was identified. The percentage varied greatly from one geographic area to another, as shown in the table. The non-spiny spore type predominated in collections from the Rocky Mountain and Pacific Coast States and from Western Canada. Other areas of relative abundance of this type were around the Upper Great Lakes and from the Gulf of St. Lawrence north into the Arctic. In most of the states east of the Rockies the *C. fragilis* complex is represented for the most part by the taxa which have been designated by the varietal names *mackayii, protrusa, simulans, tennesseensis,* and *laurentiana.* Only spiny spores were found in the collections which had been identified as these varieties. Thus, at least in North America, the non-spiny type of spore is confined to plants which, by the characters used in the current manuals, would be identified as *C. f.* var *fragilis.*

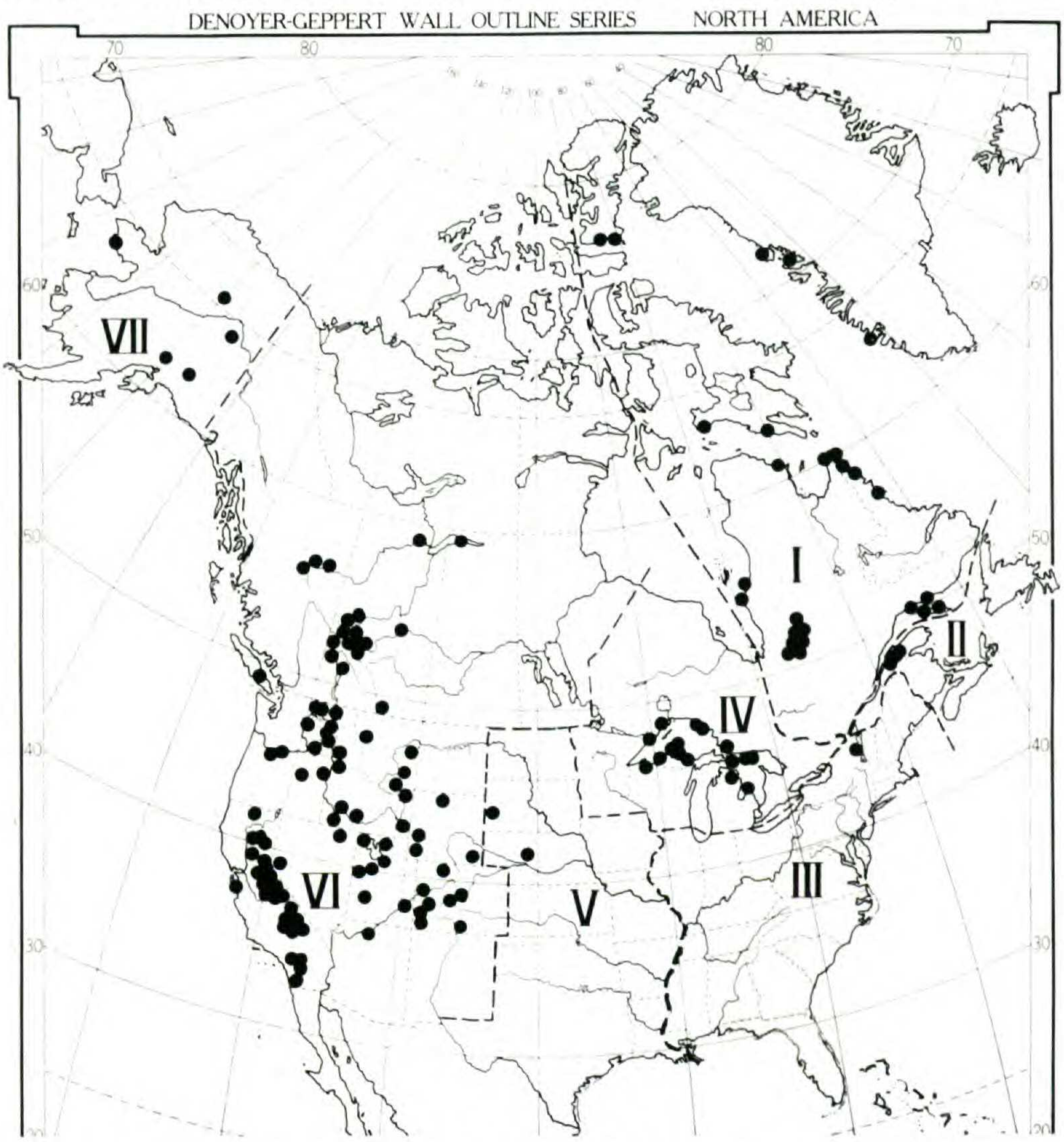

FIGURE 2. Map of distribution of Cystopteris with non-spiny spores in North America, all localities except those in Michigan based on specimens in the Gray Herbarium.

Newfoundland, the Maritime Provinces, and Gaspé were well represented in the Gray Herbarium material with a large proportion of the collections being *C. f.* var. *fragilis.* However, only three collections had non-spiny spores. All were from the vicinity of Bic, Rimouski County, Quebec, on the south shore of the St. Lawrence. Although not as plentiful as the other varieties, typical *fragilis* does occur in the Northeastern States. Only one collection had non-spiny spores. The locality data on the label is "Shores of Lake Champlain, N. Y." Four more stations have been found in Michigan since my prior report, but again the percentage of plants with non-spiny spores was small in proportion to the number of specimens examined.

Since interpretation of the plants with non-spiny spores as a species or sub-species has been based on supposed Arctic affinities it is surprising to find that this type of spore was more abundant in collections from California (83%) than in those from either Alaska (18%) or Greenland (33%).

The distribution of *Cystopteris* with non-spiny spores as found during this study is shown on the map (Fig. 2). Only collections examined by me have been mapped. Additional records, mostly for Canada and the Arctic, may be found in the literature cited.

Before the distinctive spores had been discovered the original *C. dickieana* was based on a characteristic frond pattern involving what has been described as "congested" pinnae and which still persists in cultivated plants descended from the original stock, according to Manton. However, both Manton and Löve note that non-spiny spores are found in plants with a diversity of leaf form. This was found true in the specimens in this study. Attempts to predict the spore type of herbarium specimens from their leaf architecture were incorrect more times than they were right. As described, two or more preparations were made from the same collection number where there were two or more plants. In eight such cases, plants with non-spiny and with spiny spores were found to have been collected and distributed under the same collection number. In another case, a California collection (New York Falls, Amador County, *Hansen 646*) cited by Alston as having non-spiny spores in the specimen in the British Museum was found to have spiny spores in the Gray Herbarium specimen. This seems to indicate that the field differences between plants with the two spore types are not sufficient to prevent experienced field botanists from collecting the two types as one where they grow together. Although some collections do simulate small *Woodsias*, as noted by both Wiggins and Löve, the tendency toward confusion between these two genera, as shown by the original specimen labels, is not confined to the plants with non-spiny spores. From blade texture of the specimens as well as the specimen data it was apparent that non-spiny spores occur in both sun and shade plants. The same is true for spiny spores. This bears out my own experience with the two types in Michigan.

Considerable variation in spore size was noted early in the survey. A correlation between spore size and chromosome number has been found to exist in the spiny-spored members of the genus in both Europe and North America so the scope of the survey was enlarged to include measurements of spore length. Random samples of ten spores from each slide were measured. In a sampling of more than 1,400 non-spiny spores the length, excluding the sculptured layer, was found to vary from 27 mu to 55.5 mu. This spread is nearly as great as that found for the three-leveled polyploid series in the spiny-spored types in the eastern United States. That series includes diploids ($n=42$), tetraploids ($n=84$), and hexaploids ($n=126$), of which, in Michigan material, the varieties *protrusa*, *mackayii*, and *laurentiana* are examples of the three levels. In the non-spiny spores the average size for the majority of collections falls within the sizes found for the tetraploid varieties of spiny-spored *fragilis*. The spores of the Mt. Bohemia, Michigan, plants which were investigated cytologically fall in this size class and the chromosome counts showed the plants to be tetraploid. This suggests that there may well be a three-level series in the non-spiny types (Fig. 1, B, C and D). With the exception of one collection from the Mistassini region of Quebec, all of the specimens with spores small enough to indicate a possible diploid condition were from the western United States and Alaska, but not concentrated in any one area. On the other hand, plants with spores large enough to indicate a possible hexaploid condition were mostly from Canada and Alaska, nearly all outside the range of currently known hexaploids in the spiny-spored species. More study is needed on the average size and variation in the non-spiny spores of plants for which the chromosome number is known. This will be handled best by growing the plants either from living rhizomes or from recent collections of spores, preferably the former.

Cultivation of plants from various localities is desirable also for another phase of the problem, the investigation of the various types of sculpturing. Some collections seem somewhat intermediate between spiny and non-spiny spores, and Larsen (1952) has reported intermediates from Greenland. More cytological investigation and possibly even experimental hybridization may be necessary before we can determine the relation of the non-spiny spored plants to the *fragilis* complex.

Research on the spore size and sculpturing pattern problems is limited by the fact that plants with non-spiny spores are not readily obtainable because they cannot be distinguished except by microscopic examination of the spores, a test not easily applied under even the best of field conditions. However, in June, 1960, I was able to obtain about twenty such plants from two Michigan localities. The living plants were obtained by random sampling along transects in stations for which I was fortunate in having very precise locality data. At one of these stations the sampling yielded about one-third plants with non-spiny spores while the other had a small but apparently pure stand of such plants, although plants with spiny spores were found only a few yards away. I would be glad to receive either living plants or collections with mature spores from other parts of the range.

SPECIMENS WITH NON-SPINY SPORES EXAMINED DURING THIS STUDY

All specimens cited are in the Gray Herbarium (GH) with the exception of those from Michigan which are in the Herbarium of the University of Michigan (MICH) or the herbarium of Cranbrook Institute of Science (BLH).

NEW YORK: Shores of Lake Champlain, *F. H. Horsford, June 1882*. MICHIGAN: Alpena County: near Bolton, *Hagenah 4506* (BLH); Chippew County: Near Drummond, Drummond Island, *McVaugh 11360* (MICH, BLH); Huron County: Port Austin, *C. A. Davis* (MICH); Keweenaw County: Cliff Mine, near Phoenix, *Hagenah*

3046; Mt. Bohemia, *Hagenah 2001, 2003, 3021, Hagenah & Hall 777* (BLH); Marquette County: Huron Mountains, *Hagenah 4014* (BLH); Partridge Island, Lake Superior, *A. Dachnowski* (MICH); Ontonagon County; Porcupine Mountains, *Hagenah 1166* (BLH). WISCONSIN: Ashland County: Vogt Knob, *Fassett 9220*. MINNESOTA: Cook County: Grand Portage, *Pease & Bean 26364*. SOUTH DAKOTA: Mead County: Near Tilford, *Palmer 37331*. NEBRASKA: Thomas County: Plummer Ford, Dismal River, *Rydberg 1452 (in part)*. MONTANA: Little Belt Mountains, *Scribner 445*; White Sulfur Springs, *Scribner 443*; Big Fork, Flathead Lake, *Mrs. Jos. Clemens, Aug. 5, 1908*; Gallatin County: Cottonwood Creek, *Suksdorf 552 (in part)*. IDAHO: Blaine County; Near Martin, *Macbride & Payson 3052*; Elmore County: Upper Trinity Lake, *Hitchcock & Muhlick 10368*; Latah County: Kendrick, *Henderson 4791*; Nez Perces County: Valley of Peter Creek, *Sandberg, MacDougall & Heller 119*; Owyhee County: Hot Hole, East Bruneau, *Nelson & Macbride 1905*. WYOMING: Yellowstone Falls, *Rydberg & Bessey 3506 (in part)*; Laramie Hills, *Nelson 9035*; Lincoln Gulch, *Nelson 2606*; Owens Creek, Bighorn Mountains, *J. G. Jack (in part)*; Fremont County: Sweetwater River at Farson-Lander Road, *Porter 4980*; Lincoln County: East of Afton, *Payson & Armstrong 4980*; Sweetwater County: Leucite Hills, *Merrill & Wilcox 474*. COLORADO: Rocky Mountains, Lat. 40-41, *Dr. Geo. Vasey, Powell's Colorado Exploring Expedition*; no locality, *Addison Brown* (type of *C. fragilis* var. *laciniata* Davenport); Crystal Creek, Gunnison Watershed, *Baker 261;* Tabeguache Basin, *Payson 179*; Horsetooth Mountain, *Crandall 3976*; Castillo County: Wagon Creek, *Charlotte Horner (in part)*; Montrose County: Paradox Creek, *Walker 224 (in part)*; Ute, *Payson & Payson 3911*; Park County: South Park, *Miss E. L. Hughes*; Routt County: Steamboat Springs, *Goodding 1625*; San Miguel County: Near Trout Lake, *Payson & Payson 4120*. UTAH: American Fork Canon, *Watson 1367 (in part)*; Beaver County: Delano Ranger Station, Beaver Canyon, *Maguire 19865*; Box Elder County: Drum Canyon, Raft River Range, *Maguire & Holmgren 22216*; Cache County: Between Tony Grove Lake and Naomi Peak, *Holmgren, Walker & Drummond 3576*; Grand County: LaSal Mountains, *Payson & Payson 4027*; Juab County: Granite Canyon, Deep Creek Mountains, *Maguire & Becroft 2465*; Salt Lake County: Twin Lake outlet, near Brighton, *Maguire 18656*. NEVADA: Washoe Mountains, *Watson 1367 (in part)*; Elko County: Cooper Mountain, Jarbridge Mountains, *Maguire & Holmgren 22386*. ARIZONA: Grand Canyon of the Colorado, *MacDougal 196*. CALIFORNIA: Kina River, *Rothrock 364*; High Mountain near Donner Pass, *Torrey 596*; Glen Alpine, Tahoe, *Smiley 200*; Alpine County: Pigeon Flat, *Hoover 5355*; Butte County: *Mrs. R. M. Austin, June 1879*; Butte Creek, Jonesville, *Copeland, U. of C. Plants of Calif. 602*; Eldorado County: Angora Lake, *Smiley 10*; Inyo County: Third

Lake, Cottonwood Lakes, *Alexander & Kellogg 3335;* Onion Valley, west of Independence, *Alexander & Kellogg 3162*; Lone Pine Canyon east of Mt. Muir, *Sharsmith 3298*; Los Angeles County: Bear Creek below Bear Valley Dam, San Bernardino Mountains, *Ewan 4880;* Mariposa County: Merced River Canyon, *Ware 536*; Yosemite Valley, *Abrams 4459*; Mono County: Conness Cirque near Saddlebag Lake, Tioga Pass Region, *Mason 11439*; Nevada County: Ridge south of Donner Pass, *Heller 7179*; Placer County: Mt. Lincoln south of Summit Valley, *Heller 12931*; Plumas County: *Mrs. R. M. Austin, Aug. 1882*; American Valley, *Mrs. R. M. Austin, July 1887*; Riverside County: Strawberry Valley, San Jacinto Mountains, *Grant 464;* San Bernardino County: Bear Valley, San Bernardino Mountains, *Abrams 4873;* San Diego County: Spencer Valley, near Julian, *Abrams 3798*; Santa Cruz County: Santa Cruz, *Dr. Anderson*; Tulare County: Lower Kern River Canyon, *Bacigalupi & Ferris 2451*; Crabtree Meadow, *Culbertson, C. F. Baker Dist. 4352*; South Fork Kaweah River, *Culbertson, C. F. Baker Dist. 4515;* Tuolumne County; Dardanelle, *Alexander & Kellogg 3744;* Dana Fork of Tuolumne River, Tuolumne Meadows, *Sharsmith 324*; Siskiyou County: Panther Creek Meadows, Mt. Shasta, *Cooke 13999.* OREGON: Baker County: Alder Springs, Wallowa Mountains, *Jones 6612*; Grant County: Dixie Mountain, Blue Mountains, John Day Valley, *Henderson 5587*; Hood River County: *Henderson 762*; Wasco County: Dalles of the Columbia, *Major Bullies.* WASHINGTON: Douglas County: Egbert Spring, *Sandberg & Leiberg 351*; Okanogon County: Muchamuch Lookout, *Thompson 6992*; Chesaw, *St. John, Courtney & Parker 5064;* Pend Oreille County: Z Canyon, *St. John 6469*; Spokane County: Bank of Spokane River, opposite Fort Wright, *Jennings & Jennings 8132*; Cheney, *Mrs. Susan Tucker;* Newman Lake, *Jennings & Jennings 8519*; Walla Walla County: Waitsburg, *R. M. Horner, May 1897.* ALASKA: Rapids Lodge, Richardson Highway, *Scamman 4*; Eagle Summit, Steese Highway, *Scamman 1970B*; Wiseman, *Scamman 2179*; Nome, Anvil Creek and Dexter Creek, Seward Peninsula, *Porsild & Porsild 1301*; Camp Eilson, Mt. McKinley National Park, *Nelson & Nelson 4100 (in part).*

GREENLAND: Uniîorfik Fjord, Vestside, Niaqornaq, *M. P. Porsild, Sept. 1934*; Agpatsiait, 71° 5′ N., *M. P. Porsild, July 1935*; Gothaab, *Wetherill 31.*

ELLESMERELAND: Fram Harbour, *H. G. Simmonds, July 1889*; Harbour Fjord, *Simmonds 2553.* BAFFIN LAND: Lake Harbour, *Malte 463*; Cape Dorset, *Malte 532.* LABRADOR: Razorback Harbor, Torngat Region, *Abbe 9*; Valley of the Bryant Lakes, Kangalaksiorvik, Torngat Region, *Abbe 8*; Flint Island near Manvers, *Bryant 1.* QUEBEC: Rimouski County: Bic, *Fernald & Collins 804, 808 and 809*; Anticosti Island: Riviere de la Chute, *Victorin & Rolland 27 037*; Riviere Des Caps, *Victorin & Rolland 27 051*; Mingan Islands: Ile au Fantome, *Victorin & Rolland 18090;* Grande Ile, *Victorin & Rolland*

18086; Mistassini District: Ile Andre-Michaux, *Rousseau & Rouleau 201;* Ile Manitounouk, *Rousseau & Rouleau 9;* Baie de la Chute-Cachee, Peninsule du Dauphin, *Rousseau & Rouleau 1084*; Pointe de Basalte, Peninsule du Dauphin, *Rousseau & Rouleau 1050 and 1051*; Lac Wachagami, *Rousseau & Rouleau 1306*; Opitchouane, Peninsule D'Orvel, *Rousseau & Rouleau 1157*; Ungava District: Boat Opening, Manitounok Islands, *Dutilly & Lepage 12990*; Cape Jones, James Bay, *Gardner 391237*; Diana Bay, Hudson Strait, *Gardner 39570*; Port Burwell, Hudson Strait, *Malte 121048 and 121057.* ONTARIO: Manitoulin Island: Gore Bay, *Pease & Ogden 25014*; West Bay, *Pease & Ogden 25034*; Algoma District: Garden River, *Fassett 13312;* Thunder Bay District: Jackfish, *Pease & Bean 23713 and 23717 (in part);* Sibley Township, *Taylor, Losie & Bannan 22.* SASKATCHEWAN: Cornwall Bay, Lake Athabaska, *Raup 6573.* ALBERTA: Peace Point, Wood Buffalo Park, *Raup 1454*; Edmonton, *Moss 2701a*; Nordagg, Mt. Coliseum, *Malte & Watson 1527 and 1554*; Bertha Lake, Waterton Lakes National Park, *Malte & Watson 2705*; Jasper National Park: Pyramid and Patricia Lakes, *Scamman 2789*; Miette Hot Springs, *Scamman 2400*; Medicine Lake, *Scamman 2485*; Maligne Lake, *Scamman 2576*; Athabaska Glacier, Columbia Ice Field, *Scamman 2726*; Angel Glacier, Mt. Edith Cavell, *Scamman 3401*; Jasper, *Scamman 3379.* BRITISH COLUMBIA: Selkirk Mountains, *Shaw 1095*; Asulkan Glacier Trail, Selkirk Mountains, *F. C. Prince, Aug. 1900*; Carbonate Draw, Selkirk Mountains, *Hacock, C. H. Shaw Dist. 285*; Gorge, Carbonate Draw, Selkirk Mountains, *Shaw 271*; North bank of Peace River, below Wicked River, *Raup & Abbe 4008*; Mt. Selwyn, *Raup & Abbe 3936*; Hudson Hope, Peace River Valley, *Raup & Abbe 3956*; Alberni Region, Vancouver Island, *Rosendahl 2054.*

SUMMARY: Plants distinguished only by the non-spiny (rugose-verrucose) sculpturing of the outer layer of their spores have been shown to be widespread and not uncommon in North America within most of the range of *Cystopteris fragilis* var. *fragilis.* This spore type was not found in plants identified as any of the Eastern North American members of the *C. fragilis* complex, i.e., the varieties *mackayii, protrusa, simulans, tennesseensis,* and *laurentiana;* in the endemic American species *C. bulbifera;* or in American collections of the circumpolar species *C. montana.* The presence of two entirely different spore sculpturing types in plants which cannot be distinguished by any currently known field characters or ensemble of characters seems most remarkable. However, the recognition of species on the grounds of spore sculpturing alone does not seem

justifiable at this time. The significance of spore pattern as a taxonomic character in this genus and the relationships between plants of the two spore types are problems which are likely to be resolved only by such techniques as experimental hybridization and the cytological study of the resulting progeny. — CRANBROOK INSTITUTE OF SCIENCE, BLOOMFIELD HILLS, MICHIGAN.

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